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# Energy and environmental implications of structural change in trade patterns

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## Abstract

*Trade patterns and environmental issues both local and global are related and in the light of an increasing integration of world economies the question of controlling global distribution of energy consumption and emission becomes even more important. This paper examines the importance of changing structures of foreign trade for a small open economy with respect to industrial energy consumption. Two different aspects of changing trade patterns are analysed. First the impact of changes of domestic production structure related to changes in import shares for inputs in industry are analysed. Secondly the change in final demand import- and export shares is considered. Trade induced change in energy consumption have implications for different issues as international distribution of energy consumption and emissions, and the discussion of the relevance of different policies to reduce greenhouse gases.*

*Calculations of the change in energy demand associated with the change in trade patterns are analysed using input-output techniques on detailed Danish national account and energy data. It is examined whether basic manufacturing industries and heavy industries have decreased their energy consumption by replacing energy intense elements of production with imports.*

*It is shown in this paper that the effect of a structural change in foreign trade patterns can be to increase energy demand. This is contrary to what could be expected for a country, which is supposed to export increasingly processed products with increasing inputs of skilled manpower, research and development and service.*

## 1. Introduction

Trade patterns are changing as a result of international specialisation of production and the increased integration of world economies. This is especially evident for small open economies as the Danish. In 1966 30.1% of manufacturing production was exported and this figure increased to 47.4% in 1992.

The change in trade pattern reflected in these figures has important implications for the environment and the use of resources in the economy. This study focuses on the implications for energy demand. Energy demand for input to manufacturing production in the same period only increased by 13% as the increase of production was offset by a 36% decline in energy intensity. It is an interesting issue, whether some part of this decline in aggregate energy intensity is caused by a change in the trade pattern. This issue is addressed by analysing detailed data for the manufacturing industries of Denmark. For energy demand in Denmark the size of trade flows is important and the effect of a change in the balance of trade is examined in this paper as well.

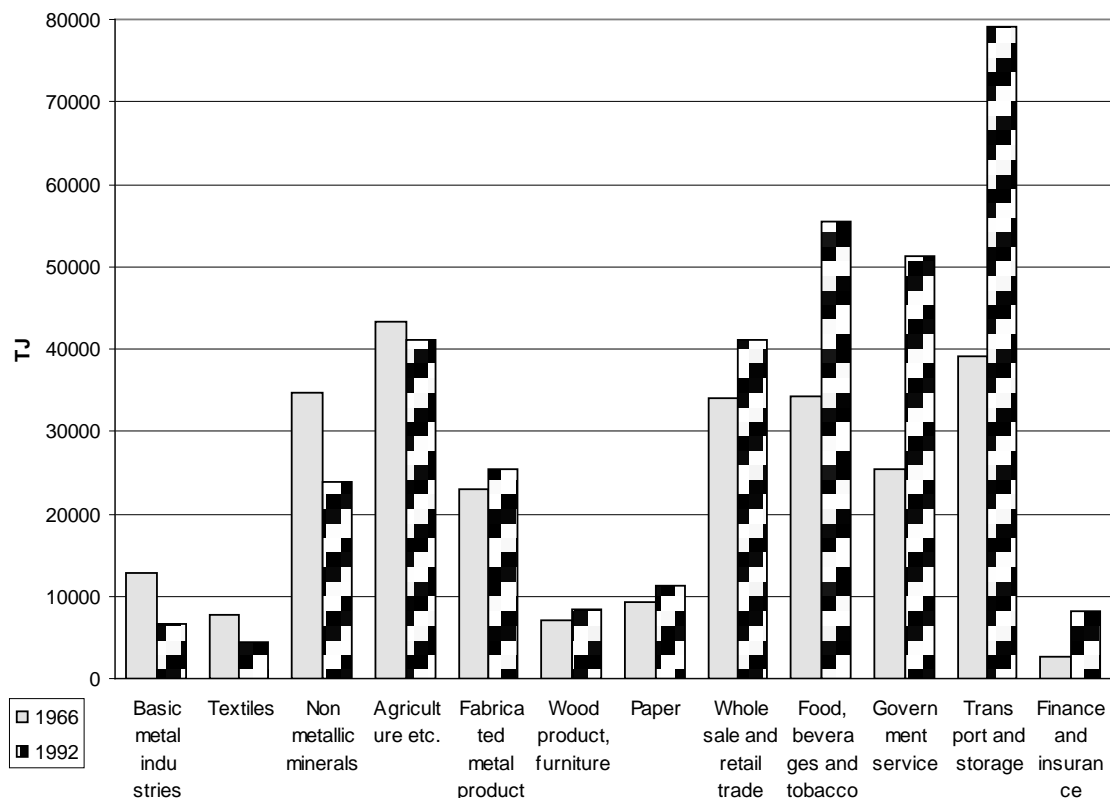
Through input-output calculations for 117 industries the consequences of change in import shares for the inputs to Danish production has been examined. The corresponding development in export shares has also been examined by analysing the

change in export share out of final demand for Danish production. Finally the change in import share of total final demand has been examined.

Energy demand and its environmental implications is a widely discussed issue also in relation to trade and globalisation. The expected effect of a change in trade pattern for an industrialised country as Denmark is a decline in energy intensity induced by specialisation in high-tech industries and industries with high content of R&D. The result of this is anticipated to be a reduction of energy demand caused by the change in trade patterns. This analysis moderates such a conclusion as the effect from the change in trade volumes (balance of trade) can dominate other effects totally.

## 2. Energy input and energy intensity in Danish industries

Danish industries on average are energy extensive relative to international levels. It is possible that the openness of the Danish economy has contributed to a specialisation in energy extensive industries leading to a decrease in the aggregate energy intensity of production. This analysis examines the relationship between changing trade patterns and Danish industrial energy demand. The effect on energy intensity at the disaggregated level is only briefly discussed.



**Figure 1 Energy input in Danish industries, 1966 and 1992**

It is obvious from Figure 1 that industries have behaved very differently with respect to the change in energy consumption from 1966 to 1992. The reason for the difference is manifold, but important determinants are:

- Different production developments caused by a change in the composition of final demand both with respect to final demand categories and goods.
- Different development in the technology and especially the energy technology used in the sectors.
- A change in the structure of foreign trade.

This analysis focuses on the third option, which in turn includes two different elements. Final demand may have shifted towards higher import shares for some goods that can be either more or less energy intensive than the average good. In the same way the import share of each input in Danish production may have shifted in a way that leads to either more or less domestic energy input in production. The effect on production and the energy demand of both these structural changes are examined in here.

The industries in Figure 1 are sorted by the relative change in energy demand from 1966 to 1992. In the service sector energy demand have increased quite substantially, while in some of the manufacturing industries and agriculture energy demand have fallen. Much of the explanation for this development must be that the service sectors share of total production have increased relative to the more primary industries, but there are at the same time changes in the energy intensity in the sectors where especially the manufacturing sectors have experienced a fall in energy intensity.

Structural change in foreign trade patterns and the increased participation in the international economy by Danish industries have influenced the production structure and hereby the demand for energy. The effect of the structural change in foreign trade will be examined by performing input-output calculations leaving the structural pattern of 1966 constant but using the total final demand and energy intensities of 1992.

### **3. Input-output calculations**

Two different, but to some extent overlapping experiments have been carried out. First the isolated effect on energy demand of the change in import shares for material input in industries have been examined. This is only one side of the increased participation in international trade. Increased import shares are probably matched by increasing export shares of production and this might have had an opposite impact on energy demand than the increase in import shares. The second experiment includes leaving both the export shares of Danish production and the import shares in final demand unchanged from 1966 to 1992.

Both experiments have been carried out based on Danish national accounts and energy balances. The available data have a time span of 27 years and this period includes both significant shifts in energy technology and energy intensity as well as foreign trade structure.

In Jacobsen (1997) a study based on a disaggregation level of 27 industries and a somewhat different methodology for input-output calculations is reported. In the present study the results based on a disaggregation of 27 industries and 117 industries are compared.

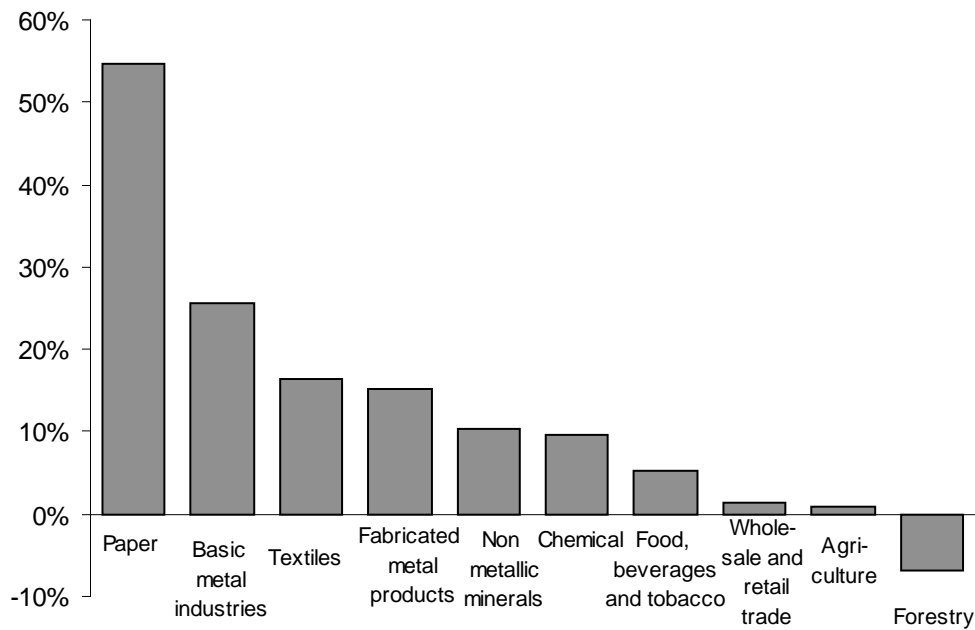
### **4. Changing import shares for industry inputs**

The data used here covers 117 industries and the energy measure used is the net energy input in GJ. Calculations of the net energy input with 1966 import shares for each of the 117 inputs in the 117 industries are carried out according to (1).

$$e92x = (I - A^s x)^{-1} e^s e ;$$

$$agx_{i,j} = (ag_{i,j} + am_{i,j}) amk_{i,j}^0 ; amk_{i,j}^0 = \frac{ag_{i,j}^0}{ag_{i,j}^0 + am_{i,j}^0} \quad (1)$$

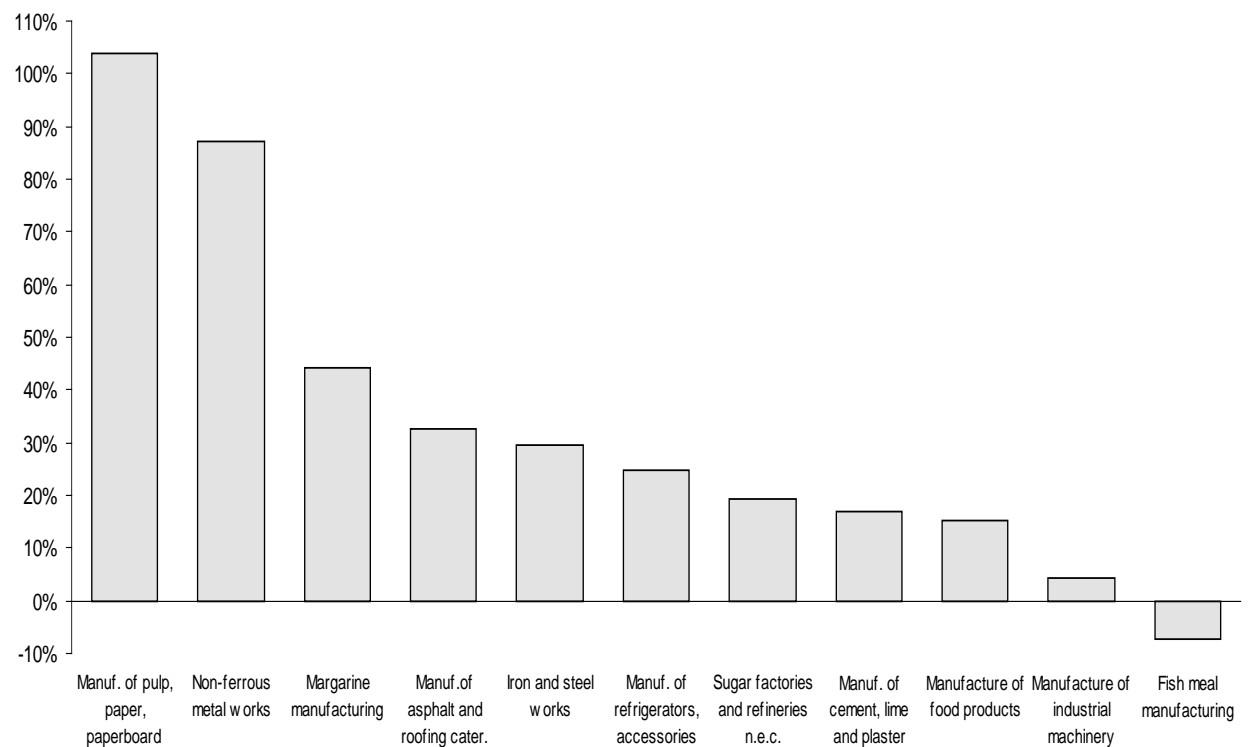
The vector of net energy input in TJ for 1992 is  $e92x$ ,  $A^s$  is the coefficients of inputs of domestic origin and  $A^m$  is the coefficients of imported inputs.  $e^s$  is final demand for domestic goods and  $e$  is the energy coefficient (net energy in TJ per mill. DKK, 1980 prices) in each production sector. The coefficient  $agx_{i,j}$  is the input of industry  $i$  production in industry  $j$  for 1992 with the import share of 1966 for each of the inputs in industry  $j$ . The imports not referable to a specific good are not included in this analysis.



**Figure 2 Energy demand in Danish industries in 1992 calculated with 1966 import shares relative to the actual energy demand in 1992**

The industries included in Figure 2 are the industries to which the structural change in import coefficients has the highest impact on their energy demand. It is the manufacturing and primary industries that are represented in this group. The corresponding impacts on service sectors are close to zero. Paper and pulp producing industries would have had 55% higher energy consumption if the import share of all inputs in Danish sectors had been like in 1966.

The manufacturing industries have experienced diminishing market shares on the domestic market for industry inputs. Without the drop in domestic industry demand, manufacturing production would have been higher in 1992 and thus the energy demand would have been higher.



**Figure 3 Difference in energy demand effect for industries at the 117 level**

The data in Figure 2 are a representation of industry aggregation from the level of calculation, 117 industries, to the 27-industry level. In Figure 3 some specific industries at the 117 level are included. Again one of the paper industries manufacture of paper and pulp shows the largest difference in energy consumption. It is the industry within the paper sector with the highest energy intensity 5.3 TJ/mill. DKK relative to an average of 0.64 TJ/mill. DKK. This observation suggest that it is the most primary activity within a sector that has been influenced most by the change in trade pattern. The basic production of paper and pulp has not been able to compete with imports and the plants have been shut down in a number of occasions. The other industries within the paper sector are much more directed towards final domestic demand. Manufacture of pulp and paper is with a contribution of 5182 TJ the largest single contributor to the difference in aggregated energy input of 22.017 TJ. The total difference originates from a few of the manufacturing industries namely: paper, fabricated metal products, chemical, non-metallic minerals, food and beverages, and basic metal industries (see Table 1.)

## 5. Change in import and export shares in final demand

The constant import shares from the experiment above are combined with constant import and export shares in total final demand. This experiment should bring some more balanced effects of the structural change in foreign trade. The vector of total final demand is recalculated using the share of final demand for domestic produced goods from the year 1966. Export share of total final demand is calculated in 1966 and used in the calculation of the final demand for domestic produced goods and services for 1992 ( $ex$ ).

When the detailed 117 level data are used the method of using shares of final demand in 1966 becomes critical. For some industries the export share in 1966 is quite high. If the

domestic demand from very low numbers have increased considerably the export will be calculated with the same percentage increase. In a few cases this leads to very high production increases if export has to be projected in line with the rest of final demand for this specific industry output. One reason for the large increase in domestic demand is the change in stocks. Some export intensive industries have large stocks due to vulnerable exports. Thus the change in stocks are excluded from domestic final demand.

$$e_{92}x = (I - A^g x)^{-1} e^g x e;$$

$$(e_t^g x + e_t^m x) = \frac{(e_t^g + e_t^m) x_t - il_t}{\left[1 - \frac{x_0}{(e_0^g + e_0^m - il_0)}\right]} \quad (2)$$

$$e^g x = il_t^g + (e_t^g x + e_t^m x) k e_0^g; k e_0^g = \frac{e_0^g}{e_0^g + e_0^m}$$

The inverted matrix from the first experiment is the same but the vector of final demand for Danish production ( $e^g x$ ) is now calculated based on unchanged export share of total final demand ( $e^g + e^m$ ) from the base year 1966. This measure of final demand is reduced for change in stocks ( $il$ ). Then the input for Danish production of the reduced domestic demand for Danish production is calculated using the inverted matrix for 1966 and 1992 respectively. These inputs are then added to the final domestic demand and exports are adjusted to follow the development of the constructed aggregate.

Export ( $x$ ) includes re-exports. The adjusted total final demand ( $e^g x + e^m x$ ) is then split by the 1966 domestic share ( $k e^g$ ) into demand for Danish production and imports.

The procedures described above results in export increasing at the same rate as final domestic demand + the induced production of domestic inputs. Import increases at the same rate as total final demand, which is the same rate as for final domestic demand.

The results of the calculations are shown in Table 1 for 27 industries, which are figures aggregated from the 117 level. Denmark is often characterised as a country producing and exporting processed products with a high and increasing content of research and development, skilled manpower and design. The change is supposed to lead to less energy content in exports and more energy content in imports, that are supposed to be increasingly dominated by intermediate products for further processing and consumer goods with relatively high energy content as cars and other durable consumer goods. This way it could be supposed that the change in the structure of foreign trade leads to less energy demand from industries in Denmark. This is not found in the material used here. To the contrary energy demand is around 7% higher today than without the change in structure and balance of trade.

Industry	Change in energy input when 1966 import shares are used	Change when 1966 import and export shares are used	Energy consumption 1992 (TJ)	Energy intensity 1966 (TJ)/mill. DKK	Energy intensity 1992 (TJ)/mill. DKK
Agriculture etc.	390	-3692	41030	1.41	0.95
Forestry	-10	-88	151	0.10	0.20

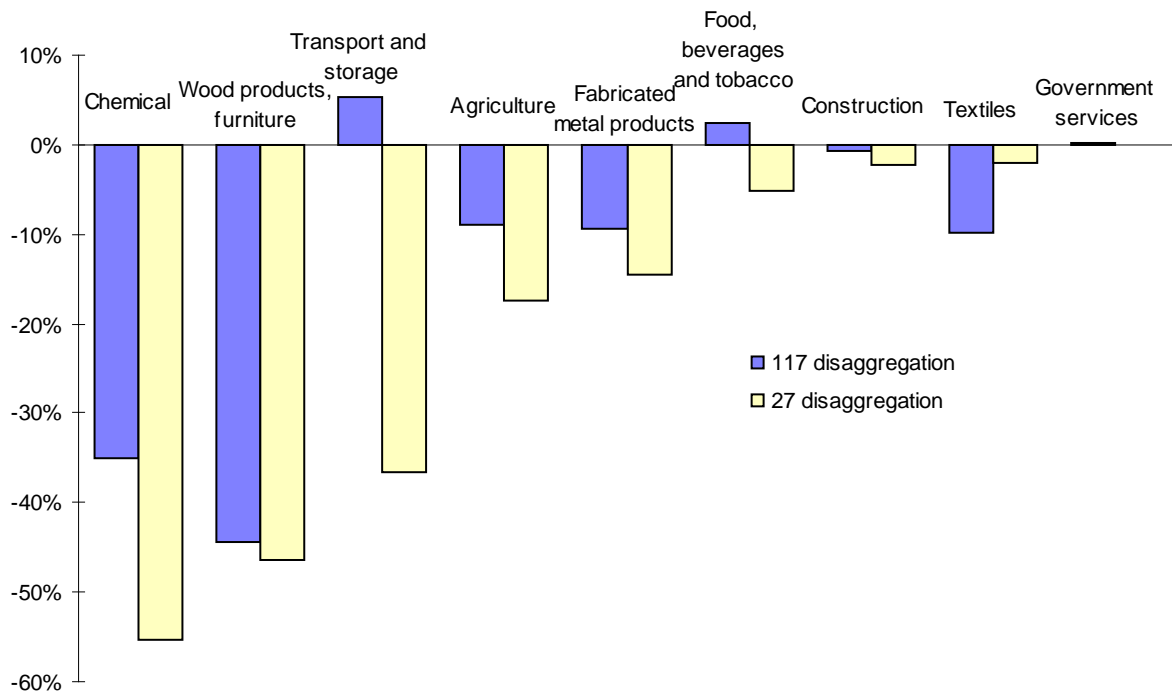
Fishing	98	-4075	11438	3.01	4.53
Mining	-535	-2333	4546	1.91	0.25
Food, beverages and tobacco	2426	1095	47208	0.72	0.59
Textiles	734	-437	4489	0.82	0.43
Wood products, furniture	172	-3762	8487	1.16	0.75
Paper	6149	2562	11245	0.79	0.64
Chemical	2668	-9719	27759	1.01	0.71
Non metallic minerals	2480	-4588	23767	5.79	3.63
Basic metal industries	1705	-2089	6640	4.95	2.34
Fabricated metal products	3867	-2378	25487	0.73	0.39
Other manufacturing industries	68	-306	1104	0.45	0.31
Electricity, gas and water	77	-99	3529	0.21	0.20
Construction	28	-108	17139	0.26	0.35
Wholesale and retail trade	554	-3633	41089	0.80	0.55
Restaurants and hotels	49	-144	8408	0.83	0.68
Transport and storage	782	4254	79226	1.27	1.25
Communication	44	-97	4303	0.83	0.38
Finance and insurance	12	34	8250	0.29	0.55
Dwellings	0	0	1924	0.04	0.04
Business services	230	-993	12613	0.26	0.34
Private education and health	3	-4	2907	0.52	0.46
Recreational and cultural service	-85	-66	1963	0.62	0.32
Household services	79	-269	8799	0.90	0.54
Other service	0	0	388	0.04	0.12
Government services	30	118	51275	0.48	0.41
All Industries	22017	-30819	455163	0.80	0.58
Manufacturing	20268	-19623	156186	1.10	0.66

**Table 1 Results of input-output calculations for 27 Danish industries**

In Figure 4 the results from the calculation at the 117 level shown in the second column expressed in relative change for some of the 27 industries are compared to the results of a calculation conducted at the 27-industry level. The industries shown are those with the largest change in energy demand and some where the aggregation level has important implications. The industries with the highest negative figures in the graph above are those that have had the best relative export performance from 1966 to 1992. If those sectors had not been this successful in export markets their energy demand would have been p to 50% less. The best performers are the chemical industry, wood products and furniture, transport and agriculture. Chemical industry includes the successful medical industry that is not energy intensive. Furniture has succeeded in export markets and the transport sector includes a large export component in the overseas fleet. The last industry with a good export performance is agriculture.

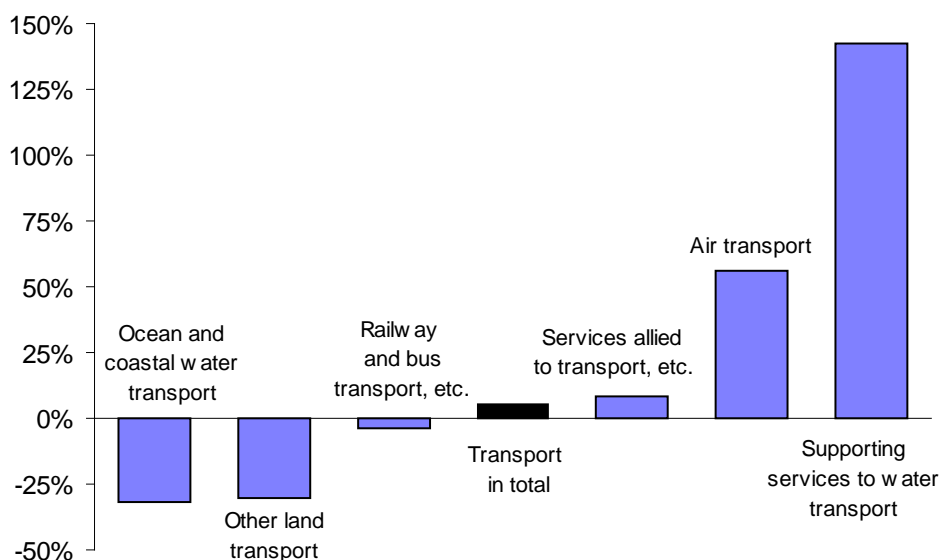
Government service has not been influenced by foreign trade changes as the import and export shares are still close to zero. For most of the other service industries that are not included in the graph the same applies, except for the transport industry which has a large and increasing share of international shipping. The only industry that would have had higher energy without the change is textiles. This manufacturing industry has undergone a radical change of composition, with more and more of the processing being located outside Denmark and the design, administration and sales activities undertaken from Denmark.





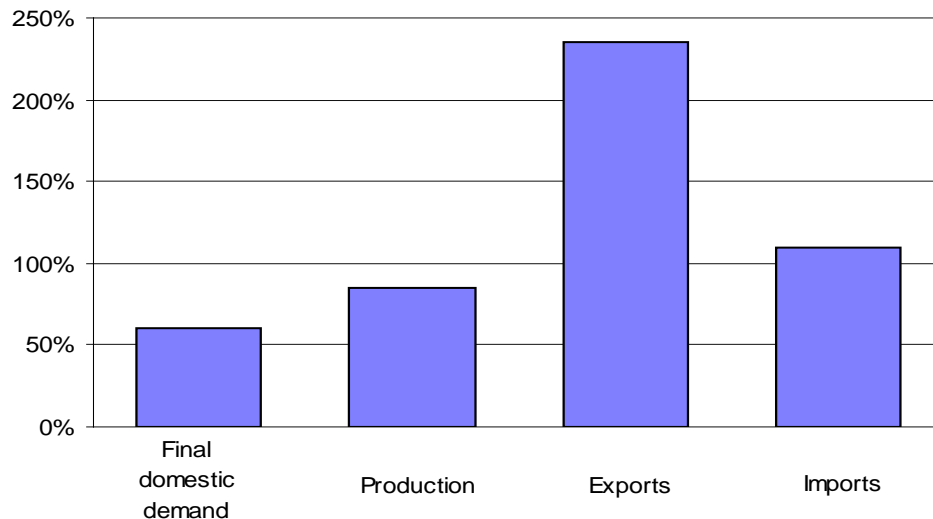
**Figure 4 Energy demand in industry with constant export and import shares in final demand relative to actual energy demand in 1992**

The importance of the level at which the calculations are conducted is evident from Figure 4. Transport is the most striking example with a large difference in the level of the result but also in the sign of the effect. This is caused by the very different energy intensities among transport sectors and different developments of trade for the individual transport sectors.



**Figure 5 Disaggregation of transport and storage**

The result for overall industrial energy consumption of the experiment is caused partly by the development of real variables shown in Figure 6. Export performance has already shown its importance as an explanation of the different results between industries. At the aggregated level export is also a main explanation for the much lower energy demand in the calculated figures for 1992 relative to actual figures.



**Figure 6 Change in major economic variables 1966-1992**

Exports have increased much more than imports and have increased about four times as fast as final domestic demand. The time period that is examined here includes a change from a substantial trade deficit to a substantial trade surplus. From a deficit of around 30% of exports in real terms for 1966 the trade balance has improved to a surplus of around 25% of exports for 1992.

The changing trade patterns have influenced energy demand in industries in 3 ways:

- Rising import shares for production inputs in industries have decreased the industry energy demand.
- Rising export shares relative to total final demand have resulted in an increase in energy demand.
- A rise in import shares relative to total final demand has resulted in less energy demand in Danish industries.

The net result is higher energy demand from industries today than would have been the case without the change in foreign trade structure. The effect of strongly increasing export relative to imports in the period studied has resulted in the dominance of the export effect and hereby an increase in energy demand.

## 6. Conclusion

In the analysis above it is shown that changes in the structure of foreign trade have an important influence on the direct energy consumption in production sectors of a small open economy as the Danish. Three different effects are identified and analysed by input-output calculations.

Increasing import shares for inputs in production has resulted in manufacturing industries experiencing a decline in market shares in the domestic market. This decline has resulted in a lower energy demand than otherwise. It is not obvious whether the decline is caused mainly by a change in the output mix within the industry (less demand from the industry itself) or it is caused by a decline in domestic market shares for the output products on average. It is the manufacturing industries and agriculture that have higher energy demand in this experiment, and especially paper and pulp is important for the total calculated higher energy demand from industries.

The two different effects of increasing import and export shares in final demand have been analysed in combination with the first effect. Increasing import shares have resulted in less domestic production and less energy demand but increasing export share of final demand have resulted in higher production and higher energy demand than would have been the case without the change in foreign trade patterns. The net effect of this experiment is that energy demand from industries is about 7% higher today than with an unchanged trade pattern.

The explanation for this higher energy demand is reflected in the comparison between industries, which shows that industries with the highest relative increase in energy demand are those with the best export performance in the period from 1966 to 1992. Export has increased twice as much as import, which has resulted in production rising more than final domestic demand.

The level of aggregation at which the calculations are conducted is important as there are important structural changes related to trade within the 27-industry aggregation. For transport this is very important. This sector is the main explanation for the difference between the 27-industry result of 19% higher energy demand today and the 7% result for calculations at the 117-industry level. It is the most energy intensive industries within the 27 grouping that have performed relatively worst with respect to trade developments.

## Acknowledgements

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